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ARS National Research Program

NRP NO. 20850 Control of insects affecting man

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This document is one of the ARS National Research Programs (ARS-NRP's) or one of the ARS Special Research Programs (ARS-SRP's). These programs provide the basic plans for research in the Agricultural Research Service. The ARS-NRP's and the ARS-SRP's are a part of the ARS Management and Planning System (MAPS). The plans identify national research objectives, describe methods for achieving these objectives, and provide the accounting and reporting system by which these program areas are planned and managed.

Each of the ARS National Research Programs and Special Research Programs outlines a 10-year plan that describes current technology and new technology expected in the 10-year period. The plan includes approaches to research and benefits expected to result from new technology. The Special Research Programs facilitate research planning and management in those exceptional circumstances where special funds are involved or a different kind of research management is needed. They provide the same general type of information as the ARS-NRP's. Both types of research programs were prepared by the National Program Staff with the cooperation of Regional Staffs and Line Managers, Technical Advisors, Research Leaders, and other scientists.

These research plans will be used for a variety of purposes. They serve to link ARS research projects to major program areas involving several agencies within the USDA program structure. ARS-NRP's and ARS-SRP's identify important national problems and describe plans for achieving technological objectives. They provide justifications for current research activities and the basis for funds for future research. They serve as the basis for program reports and for the Agency's accounting system. They also improve the communication between scientists and management, between research managers and staff scientists, between ARS and other research organizations, and between USDA and other departments, the private sector, and Congress.

These documents are dynamic statements of ARS research plans and, as new knowledge is developed, they will be continually updated to reflect changes in objectives and research approaches.

ARS-NRP No: 20850
USDA PROGRAM: 72-648

'CONTROL OF INSECTS AFFECTING HUMANS

Index of Sub-Programs and Technological Objectives

Technological Objective

New and improved technologies for the control of insects and other arthropods (mosquitoes, biting flies, filth breeding flies, fire ants, household insects, ticks, mites, lice and yellowjackets) that attack people and their belongings to improve human health and safety, recreational comfort, and agricultural production.

Cross Reference by Technological Objective to Other NRP"S

TO1. . . . . .NRP 20250 Insect control-basic/non-commodity
20260 Bio-control and insect identification
20290 Pesticides and growth regulators
20300 Pest control equipment
20350 Dairy production
20360 Beef production
20380 Sheep and other animal production
20390 Poultry production
20420 Disease control - cattle
20470 Toxicology of chemicals and poisonous plants
20480 Livestock insect control
20620 Insect control in marketing

ARS-NRP No: 20850
USDA Program: 72-648

CONTROL OF INSECTS AFFECTING HUMANS

I INTRODUCTION

Mosquitoes, chiggers, ticks, fire ants, black flies, biting gnats, lice, wasps, houseflies, fleas, cockroaches, bedbugs, and stable flies annoy and attack man causing discomfort, reduced agricultural efficiency, and reduced enjoyment of outdoor activities.

Diseases such as malaria, bubonic plague, encephalitis, typhus fever, Rocky Mountain spotted fever, cholera, dysentery, and typhoid fever are transmitted by insects. All of these diseases result in drastically reduced agricultural efficiency and can cause death. The bites or stings of imported fire ants or wasps can cause death.

The control of diseases transmitted by insects (such an dengue, encephalitis, malaria, yellow fever, typhus, and bubonic plague) is almost exclusively achieved by insect control; yellow fever is an exception where a vaccination is available and used.

Insect-transmitted diseases no longer have the devistating effects in the United States that occurred up to 30-40 years ago. However, these diseases are directly responsible for much misery in the world, reducing the working ability of millions of people throughout the world. Agricultural production is particularly affected because the very limited control effort is applied primarily in urban and not in agricultural areas.

Control technologies for insects that transmit diseases is essential to protect humans from diseases introduced into the United States, such as encephalitis in 1975. Current control methods for insects which attack humans are based primarily on repeated insecticide applications or repellents. Advanced technologies must be developed to replace insecticides which are lost because of insect resistance and regulatory actions. USAID depends to a large extent on insect control technologies developed in the United States.

The objectives of the research conducted under this NRP is to develop efficient, effective, non-polluting, and simple technologies that protect man and his possessions from diseases, annoyances and discomfort caused by insects, ticks, fleas, lice, and mites.

This Agricultural Research Service National Research Program 20850 entitled "Control of Insects Affecting Humans" contributes directly to Program 648, Research to Improve Human Health and Safety, to Operating Goal No. 2, New Knowledge to Reduce Health Hazards and Improve Family Living, and to the Department's Mission 7, Consumer Services and Human Resource Development.

II. ARS National Research Program Summary

A Current Technology

1 Problem. Humans are bitten, stung, and annoyed by mosquitoes, gnats, flies, ants, cockroaches, ticks, lice, fleas, wasps, etc. These pests reduce outdoor work efficiency and enjoyment, transmit diseases, and reduce land values, and tourism.

Mosquitoes, biting flies, ticks, lice, and fleas transmit diseases such as malaria, yellow fever, encephalitis, plague, and typhus. Control of these diseases is almost exclusively accomplished by insect control (Table II.1). In addition to disease transmission these pests are extremely annoying to people engaged in outdoor work or recreation.

Wasps and imported fire ants sting people, frequently causing severe reactions which require medical attention. These pests reduce efficiency of agricultural workers and are extremely annoying to picnicers, hikers, and campers.

Filth breeding flies such as houseflies transmit diseases and are a nuisance. Household insects such as cockroaches, fleas, bed bugs, and silverfish are extremely annoying in homes.

2 Losses/cost efficiency. Monetary losses resulting from insects affecting man are great; in addition, the losses caused by death, illness, and reduced enjoyment of outdoor activities cannot be described in monetary terms. An estimate of annual monetary losses and control costs attributed to insects affecting man totals nearly $2 billion (Table II.2). Mosquitoes and biting flies are the most serious pests, accounting for an estimated $500 million loss each year. Filth breeding flies are estimated to cost $150 million per year. The imported fire ant and household insects cause estimated annual losses plus control costs of $250 million each.

Benefits derived from controlling insects affecting man are extensive. Included are improved health, greater use of and enjoyment of outdoor recreational facilities, increased efficiency of military personnel and agricultural workers, reduced annoyance in homes, increased land value, increased tourism, etc.

3. Current control methods. Current methods of controlling insects affecting man are predominantly based on insecticides. Insecticides are the principal and frequently the only method of controlling biting flies, imported fire ants, ticks, wasps, cockroaches, filth breeding flies, mosquitoes, etc. (Table II.4).

Personal protection from mosquitoes and, to a limited extent biting flies and ticks, is achieved by the use of repellents applied to the skin or clothing. Window screens are extensively used to exclude flies and mosquitoes from houses, restuarants, and buildings. Sanitation is used to reduce populations of flies and cockroaches. Source reduction is used to a limited extent for mosquito control.

Tax-supported mosquito control districts are an effective system for mosquito control in densely populated areas.

No current control methods are based on biological control, genetic control, or population management.

No effective control methods are available for biting flies and biting gnats; satisfactory control methods are not available for insects attacking people in rural areas.

B Visualized Technologies

The anticipated increased effectiveness of technologies for controlling insects, ticks, and mites that attack humans by 1985 is about 10%; with additional support an increased effectiveness of about 15% is anticipated (Table II.3). No reduction of control costs is anticipated with current support; additional support will reduce costs about 10%.

Utilization of control technologies by 1985 with current support and with additional support is shown in Table II.4.

The major visualized technologies for each insect group are:

1. Mosquitoes:
   - (a) more effective and safer insecticides and repellents
   - (b) biological control
   - (c) genetic control
   - (d) population management

2. Biting flies:
   - (a) more effective and safer insecticides and repellents (stable fly, deer flies, biting gnats, black flies)
   - (b) biological control (stable fly)
   - (c) genetic control (stable fly)
   - (d) population management (stable fly)

3. Filth breeding flies (primarily the housefly):
   - (a) more effective and safer insecticides
   - (b) biological control
   - (c) population management

4. Imported fire ants:
   - (a) new insecticides and insecticide formulation
   - (b) development of pheromones as adjuvants to insecticide control
   - (c) biological control
   - (d) population management

5. Household insects:

   (a) new insecticides and formulations
   (b) repellents for cockroaches
   (c) population management

6. Ticks, mites, lice:

   (a) new insecticides
   (b) repellents for ticks and mites
   (c) population management for ticks

7. Wasps and yellow jackets:

   (a) new insecticides
   (b) attractants

Basic research will be required to develop new technologies for control of insects affecting man. Considerable additional support will be required for basic research on ecology, biology, physiology, pheromones, attractants, repellents, and genetics.

C Consequences

The following consequences are anticipated by achieving the visualized technologies:

1. reduce illness
2. increase enjoyment of outdoor recreation
3. increased efficiency of outdoor work including agricultural, forestry, and military
4. more insecticides used
5. more tax-supported insect control districts
6. increased tourism
7. increased land values
8. more forest fires
9. happier people

D Total Potential Benefits

Estimated benefits from achieving the visualized technologies will be both increased effectiveness of control technologies and, with additional support, reduced cost. Monetary benefits are difficult, if not impossible, to estimate. Based on the effectivenss estimates in Tables II.2 and II.3 annual monetary benefits will total about $2 million per year. With additional support, this would increase to about $5 million and reduce costs of about $2 million.

Eradication of the imported fire ants would save an estimated $250 million per year.

E Total Research Effort

The current research effort and additional ARS needs are shown in Table II.5. Additional information by type of insect and research is shown in Tables II.6 and II.7.

Priorities for increased support are for non-chemical control (biological control, genetic control, pheromones, attractants), basic research, and population management. More than half of the additional needs are for basic research.

NOTE: The expanded support level reflected in this National Research Program represents staffs views as to the additional level of staffing that can be effectively used in meeting the long-term visualized objectives for this program. These do not reflect commitments on the part of the Agency.

Table II.1. Examples of Vector-borne Human Diseases and Primary Method Used to Control the Disease (from reference no. 1).

Arthropod Pest	Disease	Primary Method of Disease Control	Area Involved[a]
Mosquitoes	Dengue	mosquito control	C, AS, A
	Encephalitis (American)	mosquito control	NA, CA, SA
	Filariasis	mosquito control	A, SA, AS, NE
	Malaria	mosquito control	tropical areas
	Yellow fever	vaccination	CA, SA, A
Biting flies	Onchocerciasis	black fly control	A, SA
	Leishmaniasis	biting gnat control	AS, NE, A CA, SA
Ticks	Rickettisosés	tick control	NA, CA, SA, AS, A
Lice	Typhus	louse control	NE, A, SA
Fleas	Bubonic plague	flea control	NA, CA, SA, AS, A

a/ A = Africa
NA = North America
CA = Central America
SA = South America
C = Caribbean
E = Europe
AS = Asia
NE = Near East

Table II.2. Estimation of Annual Losses and Control Costs Resulting from Insects Affecting Humans (Excluding Costs Related to Death, Diseases, Emergency Insect Control Programs, and Annoyance).

Pest	$ (million)
Mosquitoes	500
Biting flies	500
Filth breeding flies	150
Imported fire ant	250
Household insects	250
Ticks, mites, lice	100
Wasps, yellowjackets	25
Total	1,775

Table II.3. Anticipated Changes in Effectiveness and Cost of Controlling Insects Affecting Humans in 1985 With Current Support and With Additional Support.

Pest	% Increased Effectiveness of Control Technology With:		% Cost Reduction With:	
	Current Support	Additional Support	Current Support	Additional Support
Mosquitoes	10-15	25	0	10
Biting flies				
Stable fly	25	50	0	0
Others	0	10	0	0
Filth breeding flies	10	20-25	0	15
Imported fire ants	0	25	0	0
Household insects	10	20	0	10
Ticks, mites, lice	10	20	0	10
Wasps, yellow-jackets	10	25	0	10

Table II.4. Utilization of Control Technologies for Control of Insects, Ticks, and Mites Attacking Humans:

A = Current
B = 1985 with Current Support
C = 1985 with Additional Support

Insect		Technology					
		Insecticides	Repellents & Attractants	Biological Control	Genetic Control	Physical Control[a/]	Population Control
Mosquitoes	A	86	3	0	0	10	1
	B	76	5	2	0	12	5
	C	63	7	5	2	12	10
Biting flies	A	99	1	0	0	0	0
	B	97	2	0	1	0	0
	C	91	4	1	3	0	1
Filth breeding flies	A	70	0	0	0	30	0
	B	62	0	2	0	35	1
	C	55	0	5	2	35	3
Imported fire ants	A	100	0	0	0	0	0
	B	99	0	1	0	0	0
	C	88	0	10	0	0	2
Household insects	A	80	0	0	0	20	0
	B	73	2	0	0	25	0
	C	68	4	3	0	25	0
Ticks, mites, lice	A	100	0	0	0	0	0
	B	99	1	0	0	0	0
	C	91	5	1	0	0	3
Wasps, yellow-jackets	A	100	0	0	0	0	0
	B	85	15	0	0	0	0
	C	55	35	5	0	0	5

a/ Includes sanitation, source reduction, window screens, manure handling, etc.

Table II.5. Current and Additional Support Needs by ARS for Research on Developing New and and Improved Technologies for Control of Insects Affecting Humans.

Organization	Current Support			Additional Support for ARS	
	FY	SY	Gross $	SY	Gross $
ARS	75	27.5	1,998,000	31	3,100,000
SAES	75	38.3[a]	2,473,000	-	-
Other	75	4.5	450,000	-	-
Total		70.3	4,921,000	-	-

a/ The State of California accounts for more than 40% of this research support.

Table II. 6. Current ARS Support and Additional Needs by Insect Pest, for NRP 20850, Insects Affecting Humans

Pest	Current Support		Additional Needs	
	SY	$	SY	$
Mosquitoes	13	888,526	8	800,000
Biting flies	4	215,837	7	700,000
Filth breeding flies	1.2	107,394	2	200,000
Imported fire ants	4.5	425,155	8	800,000
Household insects	1.1	93,118	3	300,000
Ticks, mites, lice	2.2	214,173	1	100,000
Wasps, yellow-jackets	1.1	53,630	2	200,000
Total	27.5	1,997,833[a/]	31	3,100,000

a/ Additional funds (about $400,000) have been available on yearly renewable grants from the Department of Defense.

Table II.7. Current ARS Support and Additional Needs by Type of Research, for NRP 20850, Insects Affecting Humans

Type of Research	Current Support SY	Current Support $	Additional Support SY	Additional Support $
Insecticides				
conventional and IGR	8.0		2.3	
formulations and equipment	0.3		1.2	
residues	0.2		0	
Subtotal	8.5	690,175	3.5	350,000
Other chemicals				
pheromones	1.0		3.0[a]	
attractants/repellents	4.5		3.3	
formulations	0.4		1.0	
Subtotal	5.9	428,635	7.3	730,000
Non-chemical				
biological control	5.4		6.7[b]	
genetic control	2.4		1.0	
Subtotal	7.8	582,310	7.7	770,000
Basic research				
ecology/biology	3.3		4.0	
physiology	0		2.0	
genetics	1.0		1.0	
attractants/repellents	1.0		2.0	
rearing	0		1.0	
Subtotal	5.3	296,713	10.0	1,000,000
Population Management	0	0	2.5	
Subtotal	0	0	2.5	250,000
Total	27.5	1,997,833[c]	31.0	3,100,000

a/ Basic research

b/ Includes 4 SY in basic research

c/ Additional funds (about $400,000/yr.) have been available on yearly renewable grants from the Department of Defense.

III TECHNOLOGICAL OBJECTIVES

Mosquitoes

III.1 New and improved technologies for the control of insects and other arthropods that attack people and their belongings to improve human health and safety, recreational comfort, and agricultural production

A Current Technology

1 Problem. Mosquitoes are by far the most important arthropods causing annoyance and health hazards for people (1).[a/] On a world-wide basis, mosquito-borne diseases cause more human illness, suffering and deaths than other arthropod-borne diseases. The most recent catalogue (30) of mosquitoes list 2,426 species of mosquitoes. Mosquitoes breed in a variety of habitats from snow melt ice water in the polar regions to both clean and polluted waters of the temperate and tropical regions. In times of war one mosquito-borne disease, malaria, has caused more loss in terms of illness, death, and lost manpower than losses from battle casualties. The Panama Canal was not built until the problem of yellow fever transmitted by mosquitoes was solved. In the United States mosquito-borne diseases such as malaria, dengue, and yellow fever have been essentially eliminated by a combination of mosquito control and health services. However, the mosquitoes that transmit these diseases still occur and the diseases are a current threat because of the possibility of reintroduction from foreign countries. In the United States, mosquito-borne encephalitis is found throughout the country in bird and animal populations. Under conditions favorable for rapid increase of mosquito populations, (such as flooding), mosquito-borne epidemics of encephalitis frequently occur.

The annoyance caused by mosquitoes has resulted in the formation of about 260 tax-supported mosquito control districts in the United States. These districts are responsible for controlling mosquitoes so that people can enjoy outdoor activities; the effects of controlling mosquitoes has also played a large role in reduced disease transmission by mosquitoes.

2 Losses/cost efficiency. As with all insects which attack or annoy people, actual losses caused by mosquitoes are difficult to estimate. There are about 260 mosquito control districts in the United States whose 1971 budgets totaled nearly $50 million (1).

Mosquito control districts in California protect 14 million people at a cost (1974) of $11 million, for an average of $0.78/person/year (3). Mosquito control in Salt Lake City cost $0.30/person/year in 1973 (4). Most larger districts control mosquitoes by water management, source reduction, larvicides, and adulticides. Costs to individual homeowners who attempt mosquito control are unknown. Assuming 40 million households in the United States and 15% purchase a $4.00 container of insecticide for mosquito control each year, the cost would be $24 million. The total market for pesticides used for turf, garden, and household in 1971

a/ Literature cited, see p. 50.

has been estimated at $400 million (5). A significant portion of this undoubtedly is for mosquito control.

A task force on Research Needs in the Southern Region on Insects Affecting Man and his Possessions rated mosquito and other biting fly research as the top priority among arthropod problem areas (6).

Protection of individuals from mosquito attack in areas of high mosquito populations is very difficult. Repellents are about the only practical solution. The development of the lightweight net jacket impregnated with deet which will give up to 6 weeks mosquito protection has reached commercialization (7). This demonstrates the acceptance of a new technology by industry and should encourage more extensive research.

In 1974, 193 million visitor days (12 person hours/visitor day) were spent in National forests (17). Based on this it is safe to assume that a total of 600 million visitor days were spent in National or State outdoor recreational areas, including forests, parks, roadside parks, urban parks, etc. All of those people are subjected to insect attack, frequently mosquitoes. If $0.1 were spent per day per person for mosquito control, the total cost would be $60 million (this includes cost of repellent).

People living in Coastal counties of North Carolina consider mosquitoes the most important biting insect problem and are willing to pay higher taxes for mosquito control (16).

In 1975 some 2,200 cases of mosquito-borne encephalitis were confirmed with about 30 deaths. In 1971 (31, 32) the United States conducted the largest mosquito spray operation ever to stop a VEE epidemic. The cost of the entire program including spraying and immunization (not counting losses and medical and veterinary bills) was approximately $20 million.

The arbovirous diseases are a continual threat to the health of the United States; continuous introductions of these diseases, including yellow fever, will occur (32). World-wide, malaria is the most important vector-borne disease. Estimates (33) indicate more than 500 million people exist in the world with no measure of protection against malaria. In Africa it is estimated that over 95 million cases of malaria occur each year with high infant mortality. In the Americas deaths to malaria were still about 2,000 in 1967-69. Estimates of costs of malaria control range from less than $1/person/year to higher figures.

From 1957 to 1972 USAID spent $531 million on malaria control programs in developing countries. Included in this was about $153 million for 742 million pounds of DDT (1).

The resurgance of malaria in the past few years has been phenomonal. In 1968 there were 9,500 malaria cases reported in Pakistan. In 1975 there were 10,000,000 cases and by 1979 the number of cases could increase to 23 million (34).

Diseases such as malaria and yellow fever are considered by most people to be tropical or subtropical. This is not true. Records from about 200 years ago in Pennsylvania show that malaria was a problem, causing illness and death. In 1793 Philadelphia experienced a yellow fever epidemic which caused the death of 4,000 people (8% of the population) and forced temporary transfer of the President and Cabinet out of the city (35).

The Department of Defense spends millions of dollars each year to protect military personnel from attack and annoyance of insects.

With the exception of yellow fever, mosquito control is the only effective method of controlling mosquito-borne diseases (1).

The total money spent for mosquito control in the United States probably exceeds $250 million/year; losses probably are in the same range. Control costs include the cost of mosquito control districts, costs of water management procedures in Federal and State water resource facilities, cost of individual homeowners' efforts to control mosquitoes with insecticides, a significant part of the cost of window screens and netting and cost of mosquito repellents.

Benefits are impossible to estimate but are undoubtedly enormous. Reduced incidence of and disease and death from mosquito-borne diseases cannot be calculated in dollars. Additionally, other values such as outdoor recreation and tourism depend, in part, on effective mosquito control. Finally, agricultural production and land use can be increased through mosquito control. Florida's billion dollar tourist industry depends upon effective mosquito control and would not have developed without highly effective mosquito control. Without mosquito control it would be impossible to maintain the high standard of living and health of the people of the United States.

3 Current control methods. Protection of people from mosquito attack and the diseases and annoyance that mosquitoes spread falls into 3 general categories: (1) personal protection; (2) source reduction; and (3) the use of pesticides.

Personal protection involves the use of screens, netting, and clothing or the application of repellents to human skin or clothing to prevent mosquitoes from biting people directly. Such methods have no effect on the number of mosquitoes present, but simply erect a barrier between mosquitoes and the human. These methods are highly effective if used properly, but they have severe limitations in practical use. Chemical repellents applied to skin do not remain effective for more than a few hours, and their effectiveness is reduced or lost after sweating, rinsing, washing, or exposure to water. In addition, currently used repellents are oily (and therefore not completely acceptable cosmetically) and are plasticizers. Since man's activities cannot be confined to protected structures or buildings and currently used repellents are not entirely satisfactory, personal protection against mosquito attack does not provide sufficient relief from mosquito annoyance or mosquito-borne diseases.

Source reduction involves the elimination of the sites in which mosquito larvae breed. Source reduction is the most permanent method of control since elimination of breeding sites removes the production of adult mosquitoes. However, source reduction as a method of mosquito control has severe limitations. Mosquitoes breed in all types of water from the cold arctic water of melting snow to warm water of tropical climates and highly polluted to pure, fresh water. Large numbers of species of mosquitoes have adapted their development to natural as well as man-made sources of water. In many cases mosquitoes breed in waters important to maintaining other environmental values such as wildlife habitat, recreation areas, and drinking water. Thus, source reduction is a long-term, complicated, highly technical, and multidisciplinary approach to mosquito control which is costly, time consuming, and frequently impossible. Its largest impact has been in managing water resources in tidal flood lands near large centers of population. Although extreme mosquito annoyance can be reduced by this method, its effectiveness is not completely satisfactory since it is impossible within reasonable costs and time to control mosquitoes. Natural weather variations and disasters such as hurricanes, tropical storms, and heavy rains also point out our inability to control water resources.

Pesticides have been developed for mosquito control that provide a wide variety of methods of application against mosquitoes including mosquito larvicides to be applied to water and mosquito adulticides to be applied as aerosols or residual sprays. Methods of pesticide application have been developed which include the use of handheld, vehicle-mounted, or airplane equipment for use under a variety of situations. Pesticides developed and in use include the organophosphorates, carbamates, inorganics, oils, and pyrethrin-type. One insect growth regulating compound is registered for mosquito control.

Effective mosquito control, thus, depends upon organized efforts at the County, State, and Federal level to integrate the available technology to local or specialized outbreak situations and depends upon source reduction and pesticides. Individuals can obtain partial temporary relief by personal protection measures or use of pesticides around homes, camp grounds, etc.

The most advanced methods of mosquito control are being utilized except for water management. However, water management is impossible in many situations, too expensive in others, and environmentally damaging in others.

Promising approaches to new methods of mosquito control include parasites, pathogens, and predators. For some species of mosquitoes insect sterilization and genetic control appear promising. Insect growth regulators show promise, as do new types of insecticides.

Advances made in the past ten years include new pesticides for use against mosquitoes, particularly in the organophosphorus, carbamate, and pyrethroid groups. New equipment has been developed on the basis of basic research on droplet size of sprays which is highly effective and reduces costs of control by 75%. In the field of pesticides new developments only keep pace with the development of insect resistance so that the search for new pesticides only replaces those that are no longer effective.

There are no current methods of mosquito control utilizing biological control and genetic control. Pest management is practiced to a limited extent by some mosquito control districts by utilizing source reduction and pesticides; the need for pesticide application is based on adult mosquito populations.

B Visualized Technology

Effectiveness of mosquito control will be improved 10 to 15% by 1985. Cost of this improved control will be about the same as current cost. However, additional support for research will result in a 25% increase in effectiveness and a 10% reduction in cost of mosquito control by tax-supported districts because of more rapid development of population management technology utilizing a number of control methods.

1. At least five new, more effective insecticides and three insect growth regulators will be developed. The insecticides will be safer than those currently used. More efficient equipment will be developed for aerial and ground use. Additional support will be required to develop formulations for longer lasting insecticide activity.

2. Two new mosquito repellents will be developed. One of these will remain effective for 12 hours when applied to the skin. Additional support will permit the development of improved mosquito repellent formulations which will remain effective longer than 24 hours and will be cosmetically acceptable.

3. One biological control agent will be in commercial use and several others will be in the process of development. With additional support, three biological control agents can be in commercial use by 1985.

4. Genetic control (sterile male technique) will be available for practical use against one species, however, this method probably will not be used. Additional support would result in more rapid development and commercialization for use against one species.

5. Physical control methods will be limited to testing potential methods of mosquito control based on new biological data.

6. Population management will be partially developed for one species with current support. Additional support will be required for commercialization.

7. Basic research is needed in ecology, biology, genetics, attractants, repellents, and physiology. Current support is inadequate in all fields to develop mosquito control technologies for the next century.

C Research Approaches

1. Develop new insecticides, insect growth regulators, application equipment, and formulations (SR, Gainesville, FL; TBD).

2. Discover and develop new repellents and repellent formulations (NER, Beltsville, MD; SR, Gainesville, FL; TBD).

3. Discover and develop new biological control agents (SR, Lake Charles, LA; SR, Gainesville, FL; TBD).

4. Develop the sterile male technique for control of one specie of mosquito (SR, Gainesville, FL; TBD).

5. Test principals of new methods of physical control (TBD).

6. Develop population management technology for mosquito control (SR, Gainesville, FL; TBD).

7. Conduct basic research on ecology, biology, genetics, attractants, repellants, and physiology (NER, Beltsville, MD; SR, Gainesville, FL; TBD).

D Consequences of Visualized Technology

1. Happier campers, fishermen, hunters, hikers, and picnicers.
2. Less disease.
3. More insecticide and repellents used.
4. Increases in land value, more outdoor recreation, more forest fires.
5. Technology available for export.

E Potential Benefits

Monetary benefits realized from improved mosquito control technologies developed by 1985 cannot be accurately estimated. Rough estimates, however, indicate that with current support no monetary saving will result; however, effectiveness of the control technologies will be 10 to 15% better than in 1975. With additional support, effectiveness will increase 25% and costs will be reduced $50 million/year. Total monies spent for mosquito control by tax-supported districts will increase; however, cost per person per year will be reduced because of the development and implementation of population management technologies. In addition, control technologies will be less harmful to the environment. Increased outdoor recreation will result in increased land values, more tourism, and greater use of available outdoor recreation facilities.

F Research Effort

1 Current Support

Organization	Current Support FY	SY	Gross $	Additional Support for ARS SY	Gross $
ARS	75	13[a/]	888,000	8	800,000
SAES	75	20.8[b/]	1,277,000		
Other	75	-	-		
Total		33.8	2,165,000		

a/ 9.5 SY Gainesville, FL; 1.5 SY Lake Charles, LA; 1 SY Fresno, CA; 1 SY Beltsville, MD

b/ the State of California accounts for 50% of this research effort.

2 Additional Support

Eight SY should be employed as follows:

2 SY - Biological control
1 SY - Formulations
1 SY - Population management
1 SY - Basic ecology and biology
1 SY - Basic genetics
1 SY - Basic physiology
1 SY - Basic attractant and repellent research

3 Time to Reach Visualized Technology

Visualized Technology	Time to reach with: Current Support	Additional Support
New insecticides, equipment, and formulations	6	3
Repellents and formulations	10	5
Biological control	8	5
Genetic control	>10	6
Population management	>10	8
Basic research	>10	8

III TECHNOLOGICAL OBJECTIVES

Biting Flies

III.1 New and improved technologies for the control of insects and other arthropods that attack people and their belongings to improve human health and safety, recreational comfort, and agricultural production.

A Current Technology

1 Problem. Biting flies include the following:

Stable fly (dog fly), *Stomoxys calcitrans*
Black flies, *Simuliidae* spp.
Horse flies and deer flies, *Tabanidae* spp.
Biting gnats (midges), *Culicoides* and *Leptoconops* spp.

These pests affect people by sucking blood, causing a reaction which results in swelling and itching and frequently requires medication. Black flies transmit onchocerciasis (river blindness) in Africa and Latin America and biting gnats transmit leishmaniasis in Asia, Africa, and Latin America (1).

Biting flies are a serious problem in developing and maintaining the tourist industry in many parts of the United States. These pests greatly reduce enjoyment that people obtain from outdoor activities such as picnicing, hiking, swimming, camping, boating, hunting, and fishing. Homeowners are frequently prevented from outdoor activities such as gardening, backyard picnicing, and other activities. The productivity of agricultural and forest workers is greatly reduced by the attack of these pests. The efficiency of military personnel is reduced by biting flies.

2 Losses/cost efficiency. Direct losses caused by biting fly attack are not well documented. Black flies are a serious problem for the tourist industry in the Northeastern States; estimated annual losses are \$25 million (15). Travel (tourist) expenditures in the coastal counties of North Carolina for 1971 totaled more than \$62 million (16). A survey in three North Carolina counties indicated that biting flies were a serious pest. People living there were willing to pay for control, and property owners believed the value of their property would increase if fewer biting insects were present. Deer flies, horse flies, and biting gnats all were important (16). In 1974, 193 million visitor days (12 person hours/visitor day) of recreation time was spent by people in National Forests (17). Assuming that an equal number of visitor days was spent in State forests and parks, National parks, and National monuments, a total of 400 million visitor days is involved. Assuming \$0.10 was spent/visitor day on biting fly control or repellent, a total of \$40 million was expended.

The stable fly (dog fly) causes losses estimated to be several million dollars/year to the tourist industry in North Florida.

The efficiency of agricultural and forestry workers is reduced by biting fly attack. Accurate figures are not available, however, an estimate of $10 million loss is conservative (15).

Reduced efficiency of U.S. military personnel resulting from biting fly attack, both in the United States and abroad, cannot be estimated. However, the losses are serious and during a war can be immense.

More than 1 million people (10% of the population) in the Volta River Basin of West Africa are infected with Onchocerciasis (river blindness), a disease transmitted by black flies (18). This disease also is present in Mexico and South America (19).

Total losses in the United States from biting flies (including control costs) are estimated at $500 million/year.

3 Current control methods. Current technology for the control of biting flies is essentially non-existent. All of these insects are characterized by having immature stages (eggs, larvae, and pupae) that exist over large areas, frequently in water. The adults are strong flies and disperse readily. Although insecticides will kill larvae and adults, the control obtained is usually not satisfactory and always temporary. It is impossible to treat large areas of land with high dosages of insecticides because of cost, impracticability, and contamination of the environment. Insecticides that kill adults are costly and provide only limited temporary relief when applied to small areas because adults disperse rapidly into the area. Water and land management practices as well as agricultural production practices that would minimize the numbers of these insects are costly and impractical in many cases. Insect repellents are less effective against these insects than against mosquitoes.

Control of black flies was orginally developed through the application of DDT or other chlorinated hydorcarbon insecticides to rivers and streams where the larvae grow or applications of extensive areas to kill adults. Although successful in affecting control, these techniques gave only temporary relief and led to undesirable side effects on nontarget organisms. Abate is currently used to control black fly larvae in streams.

Effective control of stable flies, deer flies, horse flies, and biting gnats (midges) is limited or not available. Repellents (developed for personal protection from mosquito attack) offer some protection (7).

There is no adequate biting fly control technology available. Repellents and insecticide treatments to breeding areas offer some control when used, however, approved insecticides are lacking and effectiveness is inadequate.

Promising approaches for stable fly (dog fly) control include biological control with a parasitic wasp and the sterile male technique. There are no promising approaches for protection from attack by black flies, horse flies, deer flies, and biting gnats.

Advances during the past 10 years have been limited to development of repellents and insecticides.

There are no current methods of biting fly control based on biological control, genetics, physical control, or pest management.

Basic research is needed to develop new types of insecticides, new repellents, biological control, genetic control, and pest management. This will require research on ecology, biology, physiology, biochemistry, genetics, populations, and attractants. There is no backlog of research data, either basic or applied, on which to build future control technologies.

B Visualized Technology

Overall protection of people from biting fly attack will be 25% more effective in 1985 then in 1975. Control technology for stable flies will be developed within 10 years with current support. Cost of this control technology will be reasonable (five cents or less/tourist/day). No control technology will be developed for control of other biting flies with current levels of zero support. With additional support, adequate control technology will be developed for black flies and biting gnats and progress will have been made for protection against deer flies and horse flies.

1 At least two new insecticides, and one new insect growth regulators, will be developed for control of immature stages of the stable fly within 5 years. New insecticides will be available for control of adults with additional support. More effective insecticide application equipment will be developed, as will improved formulations. Additional support will be needed to develop insecticides for controlling black flies, deer flies, horse flies, and biting gnats.

2 Two to four new, longer lasting, effective biting fly repellents will be developed with additional support. Formulations employing controlled release of repellents will be developed which will result in one repellent treatment remaining effective for 12 hours or more with additional support. Development of attractants will depend on additional support.

3 Biological control of the stable fly will be commercialized within 6 years. Additional support will be required to discover biocontrol agents for other biting flies.

4 Genetic control (sterile male technique) for stable fly control will be developed in 5 years. With additional support, the potential of genetic control for black flies will be known within 10 years.

5 Little development is anticipated of physical control technologies for biting flies.

6 Population management in large areas will be possible for the stable fly, using a combination of control technologies. Additional support will be required to develop population management for black flies and other biting flies.

7 The lack of basic research on biting flies is preventing development of physiologically based insecticides, more specific repellents, slow development of biocontrol (except for the stable fly), and in effect is the cause of no current adequate control technology available at any cost.

C Research Effort

1 Develop new and improved insecticides, formulations, and application equipment, (SR, Gainesville, FL; TBD).

2 Discover new biting fly repellents and develop longer lasting formulations and conduct research on biting fly attractants (SR, Gainesville, FL; TBD).

3 Develop biocontrol technology for stable fly and discover biocontrol agents for black flies, deer flies, horse flies, and biting gnats (SR, Gainesville, FL; TBD).

4 Develop genetic control for stable fly and initiate development of genetic control for black flies (SR, Gainesville, FL; TBD).

5 No physical control research.

6 Evaluate population management of stable flies and initiate development of population management of black flies (SR, Gainesville, FL; TBD).

7 Conduct basic research on ecology, biology, and populations of biting flies; conduct basic research on physiology, mode-of-action of attractants and repellents, and biocontrol of black flies, stable flies,

D Consequences of Visualized Technologies

1 More insecticides used
2 Increased outdoor tourism
3 More enjoyment for tourists
4 More efficient agriculture and forest workers
5 Increased military efficiency
6 Availability of technology for export to developing countries

E Potential Benefits

Benefits accruing from new and improved technologies of biting fly control will be significant. Accurate monetary benefits cannot be documented, however, a reasonable figure is $20 million/year with current support and $80 million/year with additional support. These benefits will result from (1) increased tourism in areas where biting flies are a serious problem, (2) increased efficiency of agricultural workers, (3) increased efficiency of military personnel, (4) reduced cost for medical treatments, (5) increased enjoyment of outdoor activities, (6) contributions to solving international insect problems, and (7) improvement in the environment by use of safer insecticides and non-insecticide control technologies.

F Research Effort

1 Current Support

Organization	Current Support			Additional Support for ARS	
	FY	SY	Gross $	SY	Gross $
ARS	75	4.0 a/	345,944 b/	7	700,000
SAES	75	7.4	581,000		
Other	75	0	0		
Total		11.4	926,944		

a/ includes 0.35 SY on black flies, 3.1 SY on stable flies, balance on other biting flies; all at Gainesville, Florida.

b/ includes $130,107 for stable fly pilot test.

2 Additional Support

Seven SY's ($700,000) should be funded to conduct research on biting flies:

- 1.0 SY - Insecticides (black flies, biting gnats)
- 1.0 SY - Repellents (black flies, biting gnats, horse flies, deer flies)
- 1.0 SY - Biological control (black flies, biting gnats, horse flies, and deer flies)
- 0.5 SY - Genetic control (black flies)
- 0.5 SY - Population management (stable flies, black flies)
- 1.0 SY - Basic research on repellents (stable flies, black flies, horse flies, and deer flies)
- 1.0 SY - Basic research on ecology (black flies, biting gnats, horse flies, and deer flies)
- 1.0 SY - Basic research on rearing (black flies, biting gnats, horse flies, and deer flies)

3 Time to Reach Visualized Technology

Visualized technology	Years to achieve with: Current Support	Additional Support
Insecticides, formulations, equipment, attractants:		
stable fly	4	4
black flies	>10	4
biting gnats	>10	4
horse and deer flies	>10	8
Repellents:		
stable fly	7	4
black flies	>10	5
horse and deer flies	>10	6
biting gnats	>10	5
Biological control:		
stable fly	6	4
black fly	>10	8
biting gnats	>10	8
horse and deer flies	>10	8
Genetic control:		
stable fly	5	5
black fly	>10	8
Population Management:		
stable fly	8	5
black fly	>10	7
Basic Research	>10	5

III TECHNOLOGICAL OBJECTIVES

Filth Breeding Flies

III.1 New and improved technologies for the control of insects and other arthropods that attack people and their belongings to improve human health and safety, recreational comfort, and agricultural production

A Current Technology

1 Problem. Filth breeding flies include the housefly (*Musca domestica*) and other species of *Musca* and *Fania*. The housefly is by far the major pest, and the only species discussed here. This pest breeds in garbage, livestock manure, and human waste. The housefly (and other filth breeding flies) can transmit dysentary, typhoid fever, and cholera. Houseflies are a serious problem in both rural and urban areas. Frequently large numbers of houseflies breed at livestock installations (chicken, dairy, cattle) and infest nearby cities. Garbage dumps and sewage treatment plants often are major breeding sites for houseflies.

2 Losses/cost efficiency. Data on actual losses caused by houseflies are scarce. The State of Georgia estimated losses and control cost of $13 million in 1974 (20). California estimated $2 million for livestock only in 1974 (3). Many millions of dollars are spent annually by homeowners for housefly control. Insecticides and window screens are the major expense. Assuming 50 million households in the United States and each household buys three "vapone" strips or aerosol insecticide spray containers/year at a cost of $3 each and 10% of this is used to control houseflies, the expenditure is 50 million X $9 X 0.1 or $45 million/year. Assuming 400 million window screens in the United States prorated to cost $1/year and that 10% of this cost is to exclude houseflies, the expenditure for housefly exclusion by window screens is 400 million X $1 X 0.1 or $40 million/year. Food handling establishments must control or screen-out houseflies to avoid customer complaints and to meet sanitary regulations. These costs are not known. The total annual cost of housefly control plus losses is therefore conservatively estimated to be $150 million.

3 Current control methods. Houseflies are controlled by sanitation and/or insecticides. Insecticides have been developed to control flies by a variety of application methods: 1) larvicides, 2) adulticides (aerosol or residual sprays), 3) baits for control of adults, and 4) slow release devices (vapone strip) for use in homes and other buildings. Houseflies have shown remarkable ability to develop resistance to insecticides. In some areas houseflies can no longer be controlled with insecticides because of resistance to registered insecticides.

The most advanced technology is sanitation. This technology is used in many situations, but is too expensive in some cases. The average U.S. homeowner, and restuarant patron considers one fly to be a problem. Therefore, use of insecticides will continue to be essential.

Biological and genetic control methods have shown promise as future control technologies.

Recent advances include development of new insecticides and the commercialization of the housefly pheromone (Muscalure) as an attractant used in insecticide baits.

There are no current housefly control methods based on biological control, genetic control, repellents, or population management.

Continuing support for basic research with the housefly is needed. This insect has been used as a biochemical model for much research, some of which has lead to new types of insecticides, such as insect growth regulators. Basic studies on population dynamics and detailed ecology and biology studies in urban areas are needed to develop area wide control programs.

B Visualized Technology

Housefly control efficiency will be improved 10% within 10 years at essentially the same cost as in 1975 with current support. With additional support, efficiency will be increased 20-25% and the cost of control reduced 15%.

1 Four new insecticides including two insect growth regulators, will be developed for control of housefly adults or larvae.

2. No repellent research is visualized. Additional support will be required to develop better attractants.

3 Biological control of houseflies at livestock production facilities, garbage dumps, and sewage disposal plants will be commercialized using the parasite *Spalangia endius* within 5 years (29). Other biocontrol agents will be discovered and developed if additional support is made available.

4 Genetic control (sterile male technique) will be developed as a control technology.

5 No physical control research is visualized.

6 Population management of houseflies will be evaluated on a cost-effectiveness basis in a combined rural-urban area utilizing several control technologies, provided additional support is made available.

7 Basic research will be conducted on ecology and modeling of population. Other basic research will be conducted under NRP 20250.

C Research Approaches

1 Develop new and improved insecticides (SR, Gainesville, FL; TBD).

2 Develop better attractants (SR, Gainesville, FL; TBD).

3 Develop biological control technology and discover new biocontrol agents (SR, Gainesville, FL; TBD).

4 Evaluate genetic control technology (SR, Gainesville, FL; TBD).

5 No physical control research.

6 Evaluate population management (SR, Gainesville, FL; TBD).

7 Basic research on ecology and modeling (SR, Gainesville, FL; TBD).

D Consequences of Visualized Technology

1 Less damage to environment because of insecticides
2 Happier people
3 Less pollution caused by houseflies

E Potential Benefits

Benefits from achieving the visualized technology (with additional support) will be improved housefly control at less cost, a savings of $22.5 million. Additional savings can be realized by fewer flies and thus less bother to people. Housefly population management in urban areas which are adjacent to livestock production facilities will result in development of a new service industry for fly control. Reduced disease transmission will result from more effective housefly control.

F Research Effort

1 Current Support

Organization	Current Support FY	SY	Gross $	Additional Support for ARS SY	Gross $
ARS	75	1.2[a]	102,394	2	200,000
SAES	75	0.8	34,000		
Other	75	-	-		
Total		2.0	136,394		

[a]Gainesville, FL

2 Additional Support

Two additional SY's should be employed to conduct research as follows:

1 SY - Biological control
0.5 SY - Sterility principle and population management
0.5 SY - insecticides and attractants

3 Time to Reach Visualized Technology

Visualized Technology	Years to Achieve With: Current Support	Additional Support
New insecticides	7	4
Better attractants	7	5
Biocontrol	6	4
Genetic control	8	6
Population management	10	7

III TECHNOLOGICAL OBJECTIVES

Imported Fire Ants

III.1 New and improved technologies for the control of insects and other arthropods that attack people and their belongings to improve human health and safety, recreational comfort, and agricultural production

A Current Technology

1 Problem. The imported fire ant Solenopsis Invicta has spread since its introduction into the United States about 40 years ago into nine States from the Carolinas to Texas. If introduced, this species of imported fire ant probably can survive and become a serious problem in California and possibly parts of Oregon and Washington, the irrigated desert of the Southwest, and further north than it presently has migrated (8). S. richtari is not wide spread, occuring only in parts of Alabama and Mississippi (8). These pests originated from South America where there are numerous species of fire ants. Imported fire ants (IFA) cause problems by stinging people and animals, by building mounds which hinder farming operations, and by being a general nuisance. People, particularly children, stung by fire ants sometimes need medical attention. Newly born calves, pigs, fawns, and other animals have been killed by IFA attack. Agricultural workers are frequently stung by IFA, thus reducing productivity. IFA mounds hinder farm operation such as haying and machine harvesting row crops. Outdoor recreational activity is seriously curtailed by IFA infestations.

2 Losses/cost efficiency. The cost efficiency of IFA control is difficult to determine because accurate loss or damage data are scarce. Some individuals consider the IFA as beneficial or at least causing no damage. However, USDA and the infested States have spent about $10 million annually since about 1960 to control the IFA. These programs have been designed to control IFA over large areas.

Average cost of medical treatment for IFA stings in 1971 was $28.30, totalling $3.8 million for 136,371 patients in the nine State area (8). The IFA sting is considered a serious medical problem (21, 22). The State of Georgia reported losses and control costs for the IFA to be $23 million for 1974 (20). It has been estimated (23) that the average loss resulting from IFA in the four most heavily infested counties in North Carolina was about $320/farm in 1974. These losses resulted from combine skips (soybeans), refusal of labor to enter fields, and young pig losses.

A recent study (9) reported losses to soybean production in Loundes County, Georgia. IFA infested fields (44 mounds/acre) yielded 0.25 bushels soybeans acre less then non-infested fields because of combine skips. The soil was light, sandy loam; infestations in heavy soils would cause more losses because of harder and larger mounds. Assuming the 11 million acres of soybean in the eight southeastern States were infested with the IFA, an annual

loss of $2.75 million would be expected. Unpublished preliminary data indicates that a large percentage of the foreign matter harvested soybeans is from IFA mounds. Losses of up to $60 million have been estimated in the eight southeastern States (15).

Decrease land value in 1973 from fire ant infested States was estimated to be $500 million (8).

Total annual losses and costs of control for IFA are, therefore, estimated to be about $250 million.

3 Current Control Methods. The only method for IFA control is with an insecticide (mirex or chlorodane) Mirex is used in combination with soybean oil (food attractant) impregnated into corn cob granules (inert carrier). Mirex is used for Federal/State control programs and chlorodane is used around homes. Unfortunately the safety of both mirex and chlorodane have been challenged by EPA. If these chemicals are banned for use against the IFA, there will be no control technology available.

The use of mirex or chlorodane baits are the only and most advanced technology available; they are widely used.

Although nearly 3,000 chemicals have been evaluated for IFA control, none have proven effective. Therefore, there are essentially no promising approaches for new insecticides or new control technologies to use against the IFA.

Recent advances include an improved formulation that reduces the effective dosage of mirex by about 75%. Control can now be achieved with 0.5g mirex per acre. Advances have been made in understanding the complicated biology of the IFA; the presence of pheromone has been demonstrated; taxonomy has been clarified; preliminary data on biocontrol agents has been obtained.

There is no backlog of research data and virtually no basic research data available on which to build new control technologies.

B Visualized Technology

Effective and safe insecticidal control of the IFA will be developed by 1985 with the current level of support. The cost of this chemical control will be higher than the present mirex bait control technology. With additional support, species specific control technology will be availabe by 1985 at a cost equal to or less than current costs. In addition, biological control will be partially effective, and basic research data will provide the required information for new control technologies, including the potential for eradication.

1 One new insecticide and one new insect growth regulator will be available for IFA control by 1985. Formulations research will depend on additional support.

2 Isolation, identification, and synthesis of pheromones will require additional support. Availability of the queen pheromone offers the potential for a species specific attractant.

3 Two biological control agents will be identified, and partially evaluated by 1985 with current support. With additional support, specific biocontrol agents from South America will have been imported, evaluated, and in limited use by 1985.

4-5 No genetic or physical control research.

6 Population management is not envisualized with current support; additional support would result in preliminary population management program. Research to develop technology to stop the spread of the IFA will require additional support.

7 Basic reseach is lacking and will be negligable with current support; with additional support basic research data will be available in ecology, physiology, populations, and behavior.

C Research Approaches

1 Develop new and improved insecticides and formulations (SR, Gainesville, FL; SR, Gulfport, MS; TBD).

2 Isolate, identify, and synthesize queen, trail, and brood pheromones (TBD).

3 Discover and evaluate native and South American biological control agents (SR, Gainesville, FL; TBD).

6 Conduct research on population management utilizing several control technologies and computer modeling (TBD).

7 Conduct basic research on IFA ecology, biology, physiology, and behavior (SR, Gulfport, MS; TBD).

D Consequences of Visualized Technology

1 Fewer medical bills
2 More soybeans and other row crops
3 Increased efficiency of agricultural workers
4 More enjoyment from outdoor recreation activities

E Potential Benefits

Monetary benefits from realizing the visualized technologies will not be great. The mirex bait currently used is effective and inexpensive. New technologies will be effective but probably will be more expensive than the current mirex bait. Stopping the spread of the IFA would result in at least $200 million savings.

The use of environmentally safe insecticides, control of IFA ajacent to waterways, and the species specificity obtained with the queen pheromone will greatly reduce the environment damage resulting from IFA control.

The potential annual benefits resulting from eradication of the IFA from the United States dictate that technology be developed and eradication achieved as rapidly as possible. If the current $250 million loss plus control cost data are accurate, a yearly benefit of this amount (plus protection of uninfested areas) would accrue.

F Research Support

1 Current Support

Organization	Current Support			Additional Support for ARS	
	FY	SY	Gross $	SY	Gross $
ARS	75	4.5 a/	425,155	8	800,000
SAES	75	1.5	130,000		
Other	75	0	0		
Total		6.0	618,155		

a/ 2.5 SY at Gainesville, FL; 2 SY at Gulfport, MS

2 Additional Support

Eight SY's should be employed as follows:

1 SY - insecticides
1 SY - formulations
2 SY - biocontrol
2 SY - pheromones, attractants
1 SY - biology, ecology (spread, density, populations)
1 SY - physiology

3 Time to Reach Visualized Technology

Visualized technology	Years to achieve with:	
	Current Support	Additional Support
Insecticides and formulations	7	4
Pheromones	>10	5
Biocontrol	>10	10
Population Management	>10	10
Basic Research	>10	10

III TECHNOLOGICAL OBJECTIVES

Household Insects

III.1 New and improved technologies for the control of insects and other arthropods that attack people and their belongings to improve human health and safety, recreational comfort, and agricultural production

A Current Technology

1 Problem. This group of insects includes cockroaches, bed bugs, fleas, silverfish, firebrats, earwigs, centipedes, mites, cluster flies, fruit (vinegar) flies, and other incidental invaders of apartments, homes, restaurants, business and public buildings, assorted structures, military installations, and transportation systems. The problems caused are primarily annoyance to urban and rural dwellers; however, cockroaches can be mechanical carriers of diseases, and fleas can transmit murine typhus and plague to humans.

Cockroaches, fleas, and bed bugs are the main problem. Usually one individual of any of these three pests in a home is considered a serious problem and control measures are applied.

2 Losses/cost efficiency. The cost efficiency of household insects has not been documented. The "economic injury level" is considered by most homeowners to be anything above zero. Therefore, frequent control must be applied. These pests are usually controlled by commercial pest control operators, military personnel, or the homeowner. Insecticides are the only control technology available to rapidly eliminate these pests. Sanitation in homes and buildings will greatly reduce the rate of increase of these pests but will not eliminate them. Pets are the prime source of fleas.

Cockroaches are by far the biggest problem (24, 25) and have generated a multi-million dollar business.

Bed bugs are not known to transmit diseases to humans; however, the fact that they attack humans to obtain their blood meals causes them to be very undesirable pests. Bed bugs continue to be a problem in many countries, but have not been a major problem in the United States in recent years. However, reports of infestations in the United States are now more frequent. This indicates the possible need of better chemicals and methods to control this pest, particularly since resistance to insecticides is a current problem with two species of bed bugs that attack humans.

Several species of fleas are problems to humans. Also, flea-borne diseases such as murine typhus and plague are of greater concern to humans in many countries. Fleas have developed resistance to insecticides, therefore, continued research is necessary to develop better insecticides and methods of flea control in or near buildings and structures.

Commercial pest control companies exist in every State and in nearly every city. These companies have their own organization, the National Pest Control Operators' Association. Orkin, the largest pest control company in the United States, deals with household pests. This company has about 6,000 employees, has contracts with more than 1 million customers for routine monthly service calls at $10/month, and has annual sales of about $120 million (26). If one assumes 50% of their business is for termite control (not covered in this NRP) than this one company has sales of $60 million for household insect control. There are about 100 pest control companies in the Washington, D.C. metropolitan area (27). There are about 15,000 pest control firms in the United States that do interior pest control (24).

If it is assumed that every household in the United States spends $1 to purchase insecticide for control of cockroaches, fleas, or other household pests, the total is about $50 million. Further, the use of plastic garbage bags and frequent garbage pick up is partially to prevent cockroach populations from increasing.

The estimated U.S. market for turf, garden, and household pesticides in 1971 was $400 million (5). Assuming 15% of this was for household insect control (excluding mosquitoes and flies) the total insecticide expenditure in 1971 for household insect control was $60 million.

Total losses and control costs are estimated to be $250 million/year.

3 Current Control Methods. Insecticides and sanitation are the only methods of household insect control.

Current cockroach control methods include the use of insecticides applied by a variety of techniques: 1) residue application to surfaces, 2) dust applications in cracks and crevasses and inaccessible places, 3) bait toxicant formulations, and 4) aerosol sprays. Although these methods are highly effective in reducing infestations of cockroaches, they are not completely satisfactory for a variety of reasons. Cockroaches are present throughout the world and continually reinfest areas by moving or being transported to treated areas. Cockroaches develop resistance to insecticides requiring the continual development of new pesticides. New organophosphorus and carbamate insecticides have been developed that are effective against insecticide-resistant strains of cockroaches.

Many insecticides have been shown to be effective against bed bugs and fleas, however, these insects rapidly develop resistance to insecticides, thereby requiring the continual development of new products. Current technology for bed bug and flea control includes the use of pesticides as residual sprays and dusts. There is only a limited amount of current technology available for control of the other species of household insects since little research is done with these pests.

Insecticidal control of mites was formerly accomplished by area-wide application of organochlorine insecticides - a use no longer permitted. Two organophosphorus insecticides appear very effective in controlling mites when applied to ground and vegetation.

The control of other incidental pests has developed largely from commercialization of pesticides for cockroach, fly, and mosquito control.

Insecticides are the most advanced and most commonly used control technology.

Promising approaches for cockroach control include repellents (28), synthetic pyrethroid insecticides and pheromones which regulate aggregation and sexual behavior.

Recent progress has been made on new insecticides. Little or no progress has been made with the other household insect control technologies.

There is no backlog of data on which to develop future control technologies.

Additional basic research is needed to support non-insecticidal control technology of cockroaches, bed bugs, and fleas with emphasis on repellents, pheromones, behavior, and attractants.

B Visualized Technology

Overall effectiveness of insecticides for household insect control will increase 10% in 10 years with current support. Cost of these more effective insecticides and formulations will be higher than for presently available insecticides, however, the actual cost for control will be reduced 10% because of increased effectiveness and longer lasting effectiveness. Additional support would make it possible to develop repellents and non-insecticide methods of cockroach control. This would reduce the amount of insecticides in homes, offices, restuarants, etc.

1 Three new insecticides, including one insect growth regulator, will be developed for control of cockroaches. One new insecticide will be developed for bed bugs, and fleas. Additional support would allow formulations research.

2 One repellent will be discovered and developed to protect soft drink machines, etc. from cockroaches. These repellents also will be used to keep cockroaches out of cartons used for transport or storage of foodstuffs which are attractive to cockroaches.

3 Initiate biocontrol research if additional support is available.

4-5 Little or no progress on genetic or physical control technologies.

6 Population management utilizing insecticides, pheromones, attractants, and repellents, will be developed as non-insecticide control technologies for cockroach and flea control, providing additional support is available.

7 Additional support is needed for basic research. Basic research is needed in the areas of repellents, attractants, and behavior of cockroaches and fleas in order to develop non-insecticidal population management.

C Research Effort

1 Develop new insecticides and formulations for control of cockroaches, fleas, and bed bugs (SR, Gainesville, FL; TBD).

2 Discover and develop repellents, attractants, and pheromones for cockroaches and flea control (NER, Beltsville, MD; SR. Gainesville, FL; TBD).

3 Initiate research to discover biocontrol agents for cockroach control (TBD).

6-7 Develop non-insecticidal control technology for cockroaches and fleas (SR, Gainesville, FL; TBD).

D Consequences of Visualized Technology

1 More business for pest control operators
2 Decreased potential for disease transmission by cockroaches and fleas

E Potential Benefits

An annual savings of $20 million is estimated by 1985, assuming additional support is made available. The availability of non-insecticidal methods of insect control will result in a greatly reduced rate of development of insecticide resistance. This will result in effective insecticides lasting a longer time, saving hundreds of millions of dollars in development costs for new insecticides.

Reduced amounts of insecticides used in homes, offices, restuarants, etc. will be beneficial.

F Research Effort

1 Current Support

Organization	Current Support FY	SY	Gross $	Additional Support for ARS SY	Gross $
ARS	75	1.1 a/	93,118	3	200,000
SAES	75	7.2	308,000		
Other	75	4.0 b/	400,000		
Total		12.3	801,118		

a/ Gainesville, FL and Beltsville, MD
b/ Estimate of industry research

2 Additional Support

Three SY's should be employed to conduct research on cockroaches and fleas:

- 0.2 SY - formulations
- 0.8 SY - repellents
- 0.5 SY - pheromones
- 0.5 SY - attractants
- 0.5 SY - behavior
- 0.5 SY - biocontrol

3 Time to Reach Visualized Technology

Visualized Technology	Years to achieve with: Current Support	Additional Support
New insecticides and formulations	5	3
Repellents, attractants, pheromones	8	3
Non-insecticide control	>10	7

III TECHNOLOGICAL OBJECTIVES

Ticks, Mites (Chiggers), and Lice

III.1 New and improved technologies for the control of insects and other arthropods that attack people and their belongings to improve human health and safety, recreational comfort, and agricultural production

A Current Technology

1 Problem. Ticks, mites (chiggers, red bugs), and lice are annoying to humans in urban and rural areas. Enjoyment of outdoor recreation is particularly affected by ticks and mites. Ticks transmit diseases such as Rocky Mountain spotted fever, tularemia, Colorado tick fever, and others. There are three types of lice that attack humans: body louse, head louse, and crab louse. The body louse transmits typhus ("the scourge of armies and perhaps second or third among the great killers in history" (1)) and other diseases. Chiggers frequently cause sores from scratching; medical attention may be required.

2 Losses/cost efficiency. Losses caused by ticks, mites, and lice are not well documented. High tick populations in rural areas prevent development of recreational facilities. The State of Oklahoma estimates that losses resulting from reduced recreational development in eastern Oklahoma are $40 million/year (15). In 1975 there were 822 cases of tick-borne typhus fever in the United States (2). In urban areas, ticks can be a problem in yards and parks, particularly if dogs or rodents are present as hosts. The brown dog tick can be a pest in houses.

Mites (chiggers) are a nuisance, particularly in the southern United States.

Lice are not a serious problem in the United States, however, the threat of disease transmission cannot be overlooked.

Total losses plus control costs are estimated to be $100 million/year.

3 Current control methods. In urban areas (in and around homes) control of these pests is limited to repeated insecticide treatments. Such pests as the brown dog tick and fleas usually are associated with pets. Continuous chemical control of the pest on the animal is effective in preventing the pest from bothering humans. However, if control of the pest on the animal is not effective, than the pest must be controlled in and around the home. Chigger mites in lawns can be controlled by insecticides. Human lice are controlled by the use of insecticidal powders, ointments, or lotions.

Control of ticks and chiggers in outdoor recreational areas is more difficult than in urban areas. Repellents are somewhat effective. The application of insecticides to camp grounds and other outdoor areas with relatively high human density has been tested and found effective (1, 10, 11, 12).

The use of CO_2 as a tick attractant has greatly improved detection and monitoring.

The most advanced technology is insecticide control.

Promising approaches include area wide control of ticks and chiggers, use of CO_2 in combination with a toxicant for tick control, and potential of pheromones for use in control programs.

During the past few years new insecticides have been developed and repellents evaluated.

There is no control methods based on biological, genetic, or physical control technologies.

Basic research is non-existent and there is no backlog of research data on which to develop new control methods.

B Visualized Technology

Improved technology for tick and chigger mite control (area wide control and repellents) will result in more rapid development of outdoor recreation facilities and increased land price. Control will be 10% more effective with current support and 25% more effective with additional support. No new visualized technology is anticipated for control of lice.

1 Three new insecticides will be developed for control of ticks and chiggers.

2 One effective and long lasting repellent for protection of humans against ticks and chiggers will be developed if additional support is made available.

3-5 No biological control (except for ticks under NRP 20480), genetic control, or physical control technologies are visualized.

6 Additional support will be required to develop population management of ticks. Insecticides combined with attractants will be the primary technology developed during the next 10 years.

7 Basic research on ticks is covered in NRP 20480. Basic research on chiggers is not a high priority area.

C Research Effort

1 Develop new and improved insecticides for control of ticks and chigger mites (SR, Gainesville, FL).

2 Discover and develop new, more specific and longer lasting repellents and formulations for protection against ticks and chigger mites (SR, Gainesville, FL; TBD).

6 Evaluate population management of ticks and chiggers in large areas (10-500 acres) using insecticides and attractants (SR, Gainesville, FL; TBD).

D Consequences of Visualized Technology

1 More outdoor recreation facilities
2 Higher land prices in recreation areas
3 More insecticides used

E Potential Benefits

The potential benefits of improved tick and chigger mite control may exceed $15 million/year by 1985, assuming population management technologies are developed for recreational areas. Benefits also will accrue from protecting military personnel and reduced incidence of diseases.

F Research Effort

1 Current Support

Organization	Current Support			Additional Support for ARS	
	FY	SY	Gross $	SY	Gross $
ARS	75	2.2 a/	214,173	1	100,000
SAES	75	0.4	15,300		
Other	75	0.5 b/	50,000		
Total		3.1	279,473		

a/ Gainesville, FL
b/ Estimate of industry research

2 Additional Support

One SY is needed to conduct research on tick and mite (chigger) repellents and area wide control technology.

3 Time to Reach Visualized Technology

Visualized Technology	Years to reach with: Current Support	Additional Support
Insecticides	5	5
Repellents	10	4
Population management	8	5

III TECHNOLOGICAL OBJECTIVES

Wasps, Yellow Jackets, and Hornets

III.1 New and improved technologies for the control of insects and other arthropods that attack people and their belongings to improve human health and safety, recreational comfort, and agricultural production

A Current Technology

1 Problem. Stinging Hymenoptera such as wasps, yellow jackets, and hornets can be extremely annoying, painful, and can result in death to people who are sensitive to their stings. Wasps of the genus *Vespula* cause the most serious problems, particularly when present in large numbers around campgrounds, roadside parks, picnic areas, and fruit orchards. These species are attracted to soft drinks, meat, sandwiches, fruit, perfume, hair spray, etc. The principal species and distribution in the United States is as follows:

V. pensylvanica - western North America
V. vulgaris - North America
V. germanica - Northeast U.S.
V. squammosa - Eastern U.S.
V. maculifroma - Eastern U.S.

V. germanica is potentially the most damaging species in the United States. It was recently introduced into the northeast United States and is now as far south as the District of Columbia (14).

2 Losses/cost efficiency. In urban areas wasps are becoming a more serious problem. They are controlled with insecticides. High populations of wasps are becoming more common in urban areas.

Since wasps and yellow jackets are both harmful and beneficial (as predators) the control technology used in rural areas to prevent damage must be a management approach. Wasp protection technology for people engaged in fruit picking, camping, picnicing in parks, playgrounds or zoos, and logging and other agricultural enterprises in high wasp or yellow jacket areas is non-existent. Financial losses attributed to wasps are not accurately detailed, but include: 1) medical bills, 2) deaths, 3) automobile accidents caused by wasps flying into automobiles, 4) loss of worker productivity in fruit orchards, 5) losses to bee keepers because yellow jackets rob the bee hives, 6) reduced attendence at amusement parks and other recreation areas, and 7) loss of worker productivity in the logging industry in the Pacific northwest.

Total losses plus control costs are estimated to be $25 million/year.

3 Current control methods. Current control methods to protect people are limited to insecticidal sprays applied to nests and traps baited with catfood or other types of meat that attract adults to

feed on an insecticide in the trap. Location of nests is often difficult, especially terrestrial nests and there is danger of stings when nests are sprayed. Traps are not effective in many areas.

Around homes insecticides are normally used to eliminate wasps so as to reduce the danger of painful stings. In rural recreation areas, fruit production areas, canneries, dumps, etc. control with insecticide plus bait is not widely used because it is not effective. In addition the flight range of wasps is long and for effective control bait traps need to be placed at considerable distances from the area to be protected, in addition to within the area.

Essentially there are no effective control technologies to protect people in rural areas from wasp attack.

The most promising approach is development of powerful synthetic attractants (such as esters of butyric acid) for use as baits to protect areas where wasps are harmful to people. This approach has been successfully used for *V. pensylvanica* (13). Attractants are not available for other species.

Advances in the past few years have been limited to new insecticides. All control methods currently available are based on insecticides.

B Visualized Technology

Effectiveness of wasp (*Vespula* spp.) control will be improved 10% within 10 years with the current support and 25% with additional support. The synthetic attractants will be registered by EPA for use in protecting areas from *V. pensylvanica* and methodology developed to use this attractant in traps, or with insecticide sprays or granules. Testing of attractants for other *Vespula* spp. will be conducted. With additional support, attractants will be developed for *V. germanica* and *V. vulgaris*.

2 The use of one attractant, both alone and with insecticides, for control of *V. pensylvanica* will be developed. Additional support will make it possible to develop attractants for control of other species of wasps.

3 A survey will be conducted to determine the presence of biocontrol agents for wasp control.

4-5 No genetic or physical control research.

6 Population management will be developed using the attractant for *V. pensylvanica*.

7 Basic research data are lacking and probably will remain lacking. Additional support will be required to study the biology and ecology of *V. germanica* in the northeast United States.

C Research Effort

2 Develop attractants for wasp control (WR, Yakima, WA; TBD).
3 Survey for biocontrol agents (TBD).
6 Develop population management to protect people from wasp attack (WR, Yakima, WA; TBD).

D Consequences of Visualized Technology

1 More people using picnic areas, camping areas, etc.
2 More efficient fruit production (harvesting), logging, and fire fighting in Pacific Northwest.
3 Increase revenues from outdoor recreation facilities.

E Potential Benefits

Monetary benefits cannot be estimated, however, they will be substantial. The effective control of wasps in picnic areas, camp grounds, and fruit orchards will be inexpensive and environmentally safe. Development of control technologies for _V. germanica_ before it becomes a serious pest would result in significant benefits in the U.S. and would have world-wide application.

F Research Effort

1 Current Support

Organization	Current Support			Additional Support for ARS	
	FY	SY	Gross $	SY	Gross $
ARS	75	1.1[a/]	53,630	2	200,000
SAES	75	1.1	65,000		
Other	75	0	0		
Total		2.2	118,630		

[a/] Yakima, WA

2 Additional Support

Two SY's should be employed to conduct research on wasps:

1.0 SY - research on _V. germanica_
0.8 SY - attractant research
0.2 SY - biocontrol survey

3 Time to Reach Visualized Technology

Visualized Technology	Years to reach with: Current Support	Additional Support
Attractants	8	4
Biocontrol Survey	>10	6
Population Management	7	3
Biology and ecology of *V. germanica*	>10	5

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V APPROVAL

Recommended	Responsible NPS Scientist	21 Sept '76 Date
Concur	Assistant Administrator	Date
Concur	E. L. Corley Director, PACS	10-15-76 Date
Approved	Associate Administrator	10/29/76 Date

NOTE: The expanded support level reflected in this National Research Program represents staffs views as to the additional level of staffing that can be effectively used in meeting the long-term visualized objectives for this program. These do not reflect commitments on the part of the Agency.

LITERATURE CITED

1. Pest Control: An Assessment of Present and Alternative Technologies, Vol. V, Pest Control and Public Health. 1976. National Academy of Sciences Publication ISBN-0-309-02414-5.

2. Anonymous, 1975. Morbidity and Mortality, USDHEW, Public Health Service, Vol. 24, Numbers 49 and 53.

3. Robinson, D. W., 1975. Estimated Damage and Crop Loss Caused by Insect/mite Pests 1974. Department of Food and Agriculture, State of California, publication E-82-14.

4. Graham, J. and N. G. Graty. 1975. Urban Vector Control Services in the Developing Countries. PANS. 21 (4): 365-79.

5. Anonymous. 1973. Where are the markets? Farm chemicals, Jan., 1973, pages 26-32.

6. Anonymous. 1974. Report of a task force for the Southern Region Agricultural Experiment Stations and USDA on research needs in the southern region on insects affecting man and his possessions.

7. Grothaus, R. H., J. R. Haskins, C. E. Schreck, and H. K. Gouch. 1976. Insect Repellent Jacket: Status, Value and Potential (In Press).

8. Lofgren, C. S., W. A. Banks, and B. M. Glancey. 1975. Biology and control of imported fire ants. In Annual Review of Entomology, Vol. 20, pages 1-30.

9. Adams, C. T., J. K. Plumley, C. S. Lofgren, and W. A. Banks. 1976. Economic Importance of the Red Imported Fire Ant, Solenopsis invicta Buren. I. Preliminary Investigations of Impact on Soybean Harvest. Jour. Georgia Entomol. Soc. (In Press).

10. Grothaus, R. H., G. A. Mount, J. M. Hirst, and W. T. Keenan. 1975. ULV and HV lone star tick control. Pest Control Magazine. Nov. 1975.

11. Mount, G. A., R. H. Grothaus, K. F. Baldwin, and J. R. Haskins. 1975. ULV Sprays of Propoxur for Control of Trombicula alfreddugesi. Jour. Econ. Ent. 68 (6): 761-2.

12. Mount, G. A., R. H. Grothaus, J. T. Reed, and K. F. Baldwin. 1976. Amblyomma americanum: Control with granular or concentrated sprays of Diazinon, Propoxur, and Chlorpyrifos. Jour. Econ. Ent. 69 (2): 257-9.

13. Davis, H. G., R. W. Zwick, W. M. Rogoff, T. P. McGovern, and M. Beroza. 1973. Perimeter traps baited with synthetic lures for suppression of yellow jackets in fruit orchards. Environmental Entomol. 2(4): 569-71.

14. MacDonald, J. F., R. D. Akre, and W. B. Hill. 1974. Comparative Biology and Behavior of Vespula atrophlosa and V. pensylvanica. Melondesia. Vol. 18, pp. 1-66.

15. Authors estimate based on personnel communications with ARS and CSRS scientists.

16. Gerhardt, R. R., J. C. Dukes, J. M. Falter, and R. C. Axtell, 1973. Public Opinion on Insect Pest Management in Coastal North Carolina. Misc. public. No. 97, North Carolina Agric. Ext. Service.

17. Annonymous. 1974. National Forest Recreation: State Summary of Recreation Use; summary of activities. U.S. Forest Service

18. Annonymous. 1974. Communicable Diseases and Vector Control in 1973. WHO Chronicle, 28: 314-25.

19. Annonymous. 1976. Onchocerciasis. WHO Chronicle, 30:18-21.

20. Annonymous. 1976. Report of the Insect Survey Committee, Georgia Ent. Society. News Notes, April 1976, Georgia Ent. Society.

21. Annonymous. 1971. Health hazards of the imported fire ant. Resolution No. 38, American Medical Association, New Orleans, LA, Nov. 30, 1971.

22. Caro, M. R., V. J. Derks, and R. Jung. 1957. Skin responses to the sting of the imported fire ant. Amer. Med. Assoc. Arch. of Dermatology. 75:475-88.

23. Hunt, T. N. 1976. Survey of Agricultural losses due to the imported fire ant as estimated by North Carolina farmers. Report prepared by NC State University.

24. Pest Control: An Assessment of Present and Alternative Technologies, Vol. I. 1975. National Academy of Sciences Publication ISBN-0-309-02410-2.

25. Mead, F. W. 1976. Annual Summary of Economic Insects in Florida, 1975. Pages 36, 44. Fla. Dept. Agr. and Consumer Service, Div. Plant Industry.

26. Annonymous. 1976. The Value Line Investment Survey, pp 1834, March 26, 1976.

27. Annonymous. 1976. C & P Telephone Book, District of Columbia, Yellow Pages, pp. 544-54.

NATIONAL AGRICULTURAL LIBRARY
1022478835

28. McGovern, T. P., G. S. Burden, and M. Beroza. 1975. N-Alkanesulfonamides as repellents for the German cockroach. J. Med. Ent. 12(3): 387-89.

29. Morgan, P. B., R. S. Patterson, G. C. LaBrecque, D. E. Weidhaas, A. Benton, and T. Whitfield. 1975. Rearing and Release of the Housefly Pupal Parasite Spalangia endius Walker. Environmental Entomology 4(4):609-11.

30. Stone, A., K. L. Knight, and H. Starcke. 1959. A synoptic catalog of the mosquitoes of the world. Entomological Society of America, College Park, MD.

31. Spears, J. F. 1971-2. Largest Spray Operation Ever. J. Agric. Chem, p. 12.

32. Reeves, W. C. 1972. Can the war to contain infectious diseases be lost? Amer. J. Trop. Med. & Hyg. 21(3):251-9.

33. World Health Organization 1975. The Malaria Situation in 1973. WHO Chronicle 28:479-487.

34. Annonymous. 1975. Malaria makes a comeback - War on Hunger (report from the Agency for International Development). October 1975, pp. 27-29.

35. Annonymous. 1976. Morbidity and Mortality Weekly Report, Center for Disease Control, Public Health Service, U.S. Department of Health, Education, and Welfare. Bicentennial Issue accompanying Vol. 25, No. 25.

GPO 913-680

* NATIONAL AGRICULTURAL LIBRARY
1022478835

Emanations of Repellents for the ... mosquito. J. Med. Ent. 11(?)-367-63.

29. Morgan, N. O., ... S. Patterson, ... Lancaster, ... E. Benton, and I. Whitfield. 1975. Feeding and Release of the ... Pupal Parasite Spalangia endius Walker. Environmental Entomology 4(4):609-11.

30. Stone, A., K. L. Knight, and H. Starcke. 1959. A synoptic catalog of the mosquitoes of the world. Entomological Society of America, College Park, Md.

31. Spears, J. F. 1972-73. Report Spray Operation Year. J. Agric. Chem. p. 11.

32. Reeves, W. C. 1972. Can the war to contain infectious diseases be lost? Amer. J. Trop. Med. & Hyg. 21(3):251-9.

33. World Health Organization 1975. The Malaria Situation in 1973. WHO Chronicle 28:479-487

34. Anonymous. 1973. Malaria makes a comeback - War on Danger (Report from the Agency for International Development). October 1973, pp. 37-39.

35. Anonymous. 1976. Morbidity and Mortality Weekly Report, Center for Disease Control, Public Health Service, U.S. Department of Health, Education, and Welfare. Bibliography ... Vol. 25, No. 12.